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SHORT-TERM RETENTION IN NORMAL AND RETARDED CHILDREN AS A FUNCTION OF MEMORY LOAD AND LIST STRUCTURE

WISCONSIN RESEARCH AND DEVELOPMENT

CENTER FOR COGNITIVE LEARNING

Technical Report No. 75

SHORT-TERM RETENTION IN NORMAL AND RETARDED CHILDREN AS A FUNCTION OF MEMORY LOAD AND LIST STRUCTURE

By Robert C. Calfee

Report from the Project on Language Concepts and Cognitive Skills
Related to the Acquisition of Literacy
Robert C. Calfee and Richard L. Venezky, Principal Investigators

Wisconsin Research and Development
Center for Cognitive Learning
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Madison, Wisconsin

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This Technical Report is from the Language Concepts and Cognitive Skills Related to the Acquisition of Literacy Project in Program 1. General objectives of the Program are to generate new knowledge about concept learning and cognitive skills, to synthesize existing knowledge, and to develop educational materials suggested by the prior activities. Contributing to these Program objectives, this project's basic goal is to determine the processes by which children aged four to seven learn to read and to identify the specific reasons why many children fail to acquire this ability. Later studies will be conducted to find experimental techniques and tests for optimizing the acquisition of skills needed for learning to read.

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Reviews of research on memory processes in retardates have also been prepared recently by Belmont (1968), Scott and Scott (1968), and Goulet (1968) and should be cons·ılted for somewhat different interpretations of the findings.

R. C. C.

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ABSTRACT

Studies of recall and recognition short-term memory (STM) were reviewed, and a series of studies of serial recognition memory of normal and retarded children was described. From experiments using a recall procedure it was concluded that important variables affecting adult performance also had comparable effects on normal and retarded children. With decreasing age and IQ there were decrements in initial performance level but less evidence that forgetting occurred at a faster rate in younger and less intelligent children. Recognition memory was found to be relatively constant over a wide range of age and IQ. Evidence was presented that ability to encode and organize stimulus material depended on age and IQ. Retarded children were especially poor at adopting efficient encoding strategies and seemed relatively incapable of making use of the organizational structure of a list to facilitate storage and recall. Detailed analyses showed: (a) considerable response bias in children's recognition behavior, (b) consistent primacy and recency effects when bias was taken into account, and (c) evidence that memory for individual items was not all-or-none. Except for response biases and forgetting rate, recognition memory processes of normal and retarded children appeared to be identical to those of adults.

I
INTRODUCTION

The ability to remember several items of information over a brief period of time, 5–30 sec., is a prerequisite skill for many kinds of cognitive tasks. In order for a reader to make sense of a paragraph, for example, the essential content of the component sentences must be retained for several seconds, while higher level organization and storage is carried out. At times short-term retention of a string of items is useful in its own right, as in remembering a telephone number long enough to dial it. If one wants to remember the number for a fairly long period of time, additional efforts must be made to "memorize" it, either by repeating it, or by finding some way of chunking or organizing the information.

The work of Peterson and Peterson (1959) revived interest in short-term memory (STM). Since then, extensive investigations have been carried out in this area, most of them using college students as *S*s. Reviews of recent research can be found in Melton (1963), Postman (1964), Posner (1963), and Peterson (1966). The findings most relevant to the studies reported in this paper are that (a) forgetting of unrelated items occurs very rapidly (e.g., forgetting of a consonant string such as KVM is virtually complete after 30 sec. if no rehearsal is allowed during the interpolated interval; (b) the more unrelated are items in a list, the more rapidly individual items are forgotten; (c) both primacy and recency are observed (i.e., when *S* is asked to recall items from a fairly long list, the most recently presented items are best remembered, the items presented initially show next highest recall, and poorest performance is on the middle items); (d) forgetting often involves partial rather than all-or-none loss of information; and (e) with lists that lend themselves to organization, or when organization is imposed by teaching the *S* some kind of encoding strategy, forgetting occurs at a much slower rate.

The first three points are probably familiar to most psychologists and are well covered in the reviews referenced above. Evidence bearing on the last two points is of more recent origin, and a few additional comments may be of some value. Partial forgetting refers to the finding that, when *S* is trying to recall something and makes an error, the erroneous response is likely to resemble the correct answer in some fashion, rather than being chosen entirely at random. For example, Wickelgren (1966) has shown that in recall of consonant-letters, phonetic intrusions predominate; if there is an error in recalling G, the replacement is a consonant that sounds like G, such as C, rather than a different-sounding consonant such as M. It appears that *S* can remember some characteristics of the item (equivalent to the fact that the item ended in /i/ and was fricative), even though the exact item cannot be recalled.

The importance of list organization in recall is certainly not a new finding. However, recent studies have brought new techniques to bear on this problem, with interesting results. For example, Bower (1964) taught *S*s to convert meaningless consonant strings such as BMF into phrases such as "Bring Me Flowers" and found virtually no forgetting after 30 sec. Calfee and Peterson (in press) found that recall of a list of 8 items made up of two sublists of 4 categorically similar items was higher if the presentation was organized—i.e., if all the items in one category were presented, and then the items in the second category (e.g., *BEAR*, *FOX*, *DEER*, *TIGER*, *BEAN*, *PEA*, *CARROT*, *BEET*)—than if the items were scrambled, and that the improved recall was not primarily dependent upon improved guessing rates in the organized presentation.

In this paper, the experimental literature on STM in normal and retarded children is reviewed, and a series of studies on the effect of list length and list structure on short-term recall is presented. Relatively few developmental studies of STM are available, probably because of the difficulty of finding a suitable

task which is neither too boring nor too complex. It is most convenient to discuss experiments using recall tasks and those involving recognition tasks separately. In recall tasks the *S* must provide the response, typically a number, letter, or word, whereas in recognition tasks the set of alternatives is made available to the *S* and the response involves pointing. The recall task would seem to place greater demands on memory.

II
SHORT-TERM RECALL IN CHILDREN

The studies reviewed in this section concern, in turn, (a) tests relevant to Ellis' (1963) hypothesis of a stimulus trace deficit, (b) retroactive and proactive interference (RI and PI, respectively), and (c) list organization.

Before considering specific studies, one methodological problem must be considered. The procedure frequently used to discover whether forgetting is faster in retardates than normals consists of testing two or more populations of *Ss* for recall at several delay intervals. A significant Group-by-Delay interaction is taken as evidence of a difference in forgetting rate. As long as all groups start at the same base level when an immediate recall test is administered, the only problem with this approach is insensitivity due to boundary effects. That is, *Ss* may make no errors at all on a recall test but still differ on other measures of response strength, such as latency or confidence judgments. Because the recall measure has a boundary of 100% correct, it may be insensitive to underlying differences that may affect performance at longer delay intervals. However, if the groups start at different initial levels, as is not unusual, the interaction term from the analysis of variance may not be appropriate, depending on the model assumed. Analysis of variance is based on a linear model, but most forgetting curves are exponential. This means that the amount of forgetting during an interval is a constant proportion of the amount remaining to be forgotten. In this case, it is more meaningful to use the constant of proportionality to estimate the forgetting rate.

Suppose, for example, that two groups (A and B) are tested on eight-item lists at delays of 0 and 10 sec. Assume that at 0-sec. delay, Group A recalls 8 items and Group B 6 items, while at 10-sec. delay, 4 and 2 items are recalled by A and B, respectively. In the analysis of variance model that is likely to be used with these data, the interaction term would test whether the difference between the two groups was identical at both delay intervals, as it is in the example. A finding of no interaction is equivalent to showing that each of the four data points can be represented by a simple linear combination of the main effects due to the group and delay variables. It is also equivalent to showing that the forgetting curves are parallel to each other.

In the example above, Group A has a slower forgetting rate than Group B, since over a 10-sec. interval it lost half of the information available on immediate test, while Group B lost two-thirds. This does not imply that application of analysis of variance to recall data is inappropriate; but it does call into question the interpretation of the results of such analysis.

In studies of STM in children, it is rare to find the kind of parametric investigation in which reliable measures of recall are obtained for each group at a sufficient number of points on the delay continuum to allow precise specification of the forgetting function and estimation of parameters. From several studies discussed below in which retardates typically forget the same absolute amount as normals over a fixed time but start at lower base levels, it seems reasonable to infer that retardates forget at a faster rate than normals. However, forgetting rate is generally not defined in the literature as the *proportionate* loss of information, but as the absolute difference in probability of recall. In this review this custom will be observed, so that when it is said that two groups forget at the same rate, what is meant is that the forgetting curves are parallel. However the alternate interpretation should be kept in mind.

By comparing the performance of normal and mentally retarded children, several studies have been undertaken to test Ellis' (1963) hypothesis that the deficit in retardation can be attributed to more rapid fading of the short-term stimulus trace. His thesis was that in retardates the representation in memory of a newly arrived piece of information is weaker and fades more rapidly than it does in normal

individuals. Differences in rate of forgetting have therefore been of primary interest. Evidence bearing on this hypothesis has been mixed, but a variety of interesting substantive findings have come forth.

Two studies reported in Headrick and Ellis (1964) showed that rate of forgetting of a 6-digit array over a period of 45 sec. was identical for normal and retarded 15-year-olds (matched on CA). The 6 digits, arranged in a circular array, were presented for 50 msec.—a very brief presentation for that amount of information. Then, following a delay period, the location of the digit to be recalled was indicated by a marker light next to one of the elements in the array. Thus, until the marker light came on, the entire array had to be remembered. Ability to perceive all elements of the array was poor and there was only a slight effect of the delay interval. The retardates performed at a generally lower level than did normals, but the functions relating recall to delay were parallel. Although retardates were less proficient at reading or encoding a briefly presented stimulus, their ability to store whatever information had been obtained was comparable to that of normals. Holden (1965, 1966, 1967) reported similar findings in a series of studies with visual recognition tasks.

O'Connor and Hermelin (1965) also concluded that retardates are subject to input restrictions but have short-term forgetting rates comparable to those of normals. Normal and severely retarded children were tested for immediate recall of 3-digit numbers which were presented either simultaneously or successively at rates ranging from .13 to 3.3 sec. per digit. In the successive procedure, a slow presentation rate gives the *S* the advantage of a longer time to read each item and integrate it with previously presented digits, but the concurrent disadvantage is that the initial digits have to be remembered over a longer time span. Normals and retardates both showed the same serial position effect as presentation rate was varied—the first digit was better recalled at fast rates, and the last digit was better recalled at slow rates. In normals, an optimal tradeoff in these two processes occurred at .66 sec. per digit, while in retardates, the two processes balanced out at all presentation rates. Although the normals performed at a higher overall level than retardates, the rate at which the initial digit was forgotten was approximately the same for both groups. This led to the conclusion that input restriction, rather than forgetting, was responsible for the poorer recall in retardates.

Although the two groups appeared to handle successively presented material similarly, there were differences in recall of simultaneously presented numbers. Except for the fastest rate normals made more errors with successive than simultaneous presentation. With rapid simultaneous presentation, errors piled up at the third digit, which suggests that there was not enough time to read all three digits. Under simultaneous presentation retardates made a substantial number of errors at each of the serial positions. The integration of the 3 digits apparently posed special problems for retardates. For example, at the slowest presentation rate, normals and retardates made the same number of errors at each serial position, but retardates were less likely to recall all 3 digits in their correct locations.[1]

In an earlier study, Hermelin and O'Connor (1964) also found evidence of impaired rehearsal or encoding capacities in retardates. Their *S*s, retardates ranging from 12 to 18 yrs. and normals matched on MA (6 to 7 yrs.), were required to recall a digit string after 2- to 12-sec. intervals which were either blank or filled with a pronunciation task, involving either common or rare words. Digit string length ranged from 2 to 5 items, depending on the span of the individual *S*. The mean digit spans of the two groups were not given; presumably, the retardates had shorter spans and were therefore required to remember less—a factor which should tend to reduce group differences. Normal children forgot very little during intervals in which they did not have the additional pronunciation task. In fact,

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[1]After this review was prepared, a draft report on a series of studies of serial recognition memory for a sequence of 9 digits was received from Ellis (1968). While a recognition task was employed, the fact that digits were used make it appropriate to consider the report here. The most pertinent findings, based on a population of older retardates (CA = 20 yr., IQ = 61), were that rate had no effect on performance, and that primacy effects were negligible, but appeared to increase with training. Performance was much poorer than for CA-matched normals, who exhibited marked primacy, and for whom slower presentation rate improved performance. It is worth comparing the Ellis results with those of O'Connor et al. O'Connor found rate effects in retardates with a subspan digit string, Ellis found no effect with a supraspan string. It would appear useful to explore the joint effects of list length and presentation rate.

they showed slightly better performance with a 12-sec. delay than with no delay, as in the inverse forgetting experiments of Crawford, Hunt, and Peak (1966). The younger retardates had forgotten most of the string by the end of a 12-sec. blank interval; older retardates showed little loss. When the delay interval was filled with the rehearsal-preventing pronunciation task, recall was substantially poorer for both normals and retardates, but the latter group appeared to forget more rapidly.

Over the course of an unfilled interval in young retardates, rapid forgetting occurred in spite of the opportunity for rehearsal. It is possible that the retardates did not rehearse, perhaps because of poor motivation or attention. (There were 72 trials per session—a lot of testing for retarded children.) An alternative hypothesis is that the rehearsal activities of normals involve reorganization of digit strings into more compact subunits or chunks, and that it is this ability which is poorly developed in retardates.

Fagan (1966) has reported results that complement those of the Hermelin and O'Connor (1964) study. Slightly retarded 11-year-olds and normal 9-year-olds were compared on a 4-digit retention test with filled (color naming) or unfilled intervals. Both normals and retardates showed some loss (about 5%) after an 8-sec. unfilled interval and much more forgetting after a filled interval. Retardates again performed more poorly under all conditions, but forgetting curves were parallel to those of normals. The experiment was equivalent to Hermelin and O'Connor's in most respects; Fagan's retardates had higher IQ's and his normal children were a little older. Both groups in Fagan's study showed some forgetting with an unfilled delay, rather than the constancy observed by Hermelin and O'Connor, perhaps because of the longer list—4 digits instead of 3.

Parenthetically, in all three studies which used digit sequences presumably within the span of both normals and retardates, considerable variation in performance was observed at short delays and with unfilled intervals. For example, in O'Connor and Hermelin (1965), 5- to-8-year-old normals had error rates of about 5%, 18-year-old retardates about 10%, and 12-year-old retardates about 25%. In Hermelin and O'Connor (1964), in which 6-year-old normals were matched with 15-year-old retardates, the error rates were 34 and 58%, respectively. In the former study, the digits were read to the child, while in the latter study, the digits were shown one at a time. From the conflicting evidence on the relative ease with which material presented in a visual or auditory mode can be handled, it is not clear what effect is to be expected from differences in mode of presentation. In Fagan's (1966) experiment, in which digits were also read to the children, the observed error probabilities were 10 and 25% for 9-year-old normals and 11-year-old retardates, respectively. These probabilities agree well with O'Connor and Hermelin, which indicates that presentation mode may be important.

In the studies by O'Connor and Hermelin digit span was pretested and the length of the digit strings used in the testing was always less than or equal to the pretest value; the error rate should therefore have been close to 0. It is apparent that under conditions of little or no RI, there was a substantial reduction in digit span over the testing series for both normals and retardates, possibly due to PI from preceding lists. The reduction appears to be relatively greater for retardates than for normals.

Returning to the problem of RI, Metzger, Simon, and Ditrichs (1965) investigated the effects of various types of interpolated tasks on recall. Retarded adults were required to remember a single word over a delay period (up to 16 sec.) which was filled with one of several types of interpolated activity. If the delay period was blank or filled with music, or if *S* was asked to rehearse the word, little forgetting occurred. If an unrelated activity such as color naming was required, or if acoustically similar material (other words) was presented, recall was poorer. It is interesting to note that older retardates showed no loss during an unfilled delay interval (cf. Ellis, 1968). While no normal controls were tested, the general pattern of results was what one would expect in light of the work on acoustic interferences in STM (Wickelgren, 1966; Dale & Gregory, 1966) and difficulty of information processing in an interpolated task (Posner & Rossman, 1965).

Borkowski (1965), using the Keppel and Underwood (1962) design for studying PI in STM, examined the effects of PI in retarded adults (IQ = 64, CA = 26) and MA-matched children, and in high (102) and low (81) IQ hospitalized adults. The procedure consisted of a series of trials on which a consonant trigram or bigram was presented for recall over a filled delay interval (up to 16 sec.). The original finding of Keppel and Underwood was that on early trials (little PI from preceding items) there was little forgetting over the delay interval, whereas after a number of

trials had been run, numerous errors occurred at long delays. Loess (1964) showed that intrusion errors in this design could be traced to interference from items presented on preceding trials. The clearest result in Borkowski's experiment was that, over a 16-sec. delay, retardates and low IQ adults were much more affected by PI than were normals and high IQ normals, respectively. On early trials, all *S*s performed at about the same level. After 3 or 4 trials, however, recall by the low IQ groups had dropped to half the initial level, while recall scores of the high IQ groups declined only slightly. The low IQ groups seemed unable to maintain a distinction between the item which had just been presented and previously presented items; consequently, they made about twice as many intrusion errors. Instructions were not reported. However, in STM experiments of this sort *S*s may attempt to remember everything that has been presented unless specifically instructed otherwise. There is no way of telling whether the groups with poorer intelligence were trying to remember more of the previous items (perhaps due to an inadequate understanding of instructions) or whether all *S*s were trying to remember everything, the poorer *S*s being less able to keep the items correctly ordered in memory.

Spitz (1966) has argued that input organization is an especially important factor in the memory performance of retardates. He suggests that, while normals seek to encode or transform information into a simpler, more organized format, "retardates frequently do not act on the incoming material, or act on it in ways that hinder learning and memory [p. 53]." In addition to reviewing studies on free-recall and paired-associate learning (which are not immediately relevant to this paper), Spitz presented a study on the effect of organizational variables on STM in normals and retardates. The classical digit span procedure was used—the child was shown a series of cards on which were printed lists of digits, each list containing one more digit than the last, until a recall error occurred (or to a maximum length of 8 digits). Lists were presented in an ungrouped (U) or grouped (G) format (digits were equally spaced or were clustered in pairs where possible, e.g., 25836 vs. 25 83 6 in a 5-item list). Moderately retarded adolescents matched on MA to 9-year-old normals were assigned to one of three conditions. All *S*s were tested twice. In Condition U-G, first the ungrouped span was determined, and then the grouped span; in Condition G-U, this order was reversed; and in Condition U-U, both tests were ungrouped.

Normals performed at a somewhat constant level under all conditions (mean digit span of about 6 items), with only slight facilitation for G lists. Retardates performed more poorly than normals under all conditions (mean span of about 4.5 items), but could recall an average of almost 1 digit more in the G than the U format. The span for the U test in Condition G-U was only slightly above that for the U test in Condition U-G, leading Spitz to conclude that retardates could not profit from experience with grouping. However, either because of PI or fatigue or both, there was a decrease in span of about half a digit from the first to the second test in Condition U-U. Taking this drop into account, it is apparent that there was some transfer from training on G to U material; the increase of .5 digit in G-U compared to U-U was not statistically reliable, however. A recent study by Wickelgren (1967) suggests that greater differences might have been observed under slightly changed conditions, viz., if groups of 3 digits had been used, and if, in the recall procedure, the grouping was emphasized by asking for recall in groups of 3.

Following a series of experiments using Broadbent's (1958) dichotic listening task, Neufeldt (1966) reached a conclusion similar to that of Spitz, viz., that normal *S*s are more disposed to adopt encoding strategies in the storage and retrieval of information than are retardates. Neufeldt's retarded *S*s were 13-year-old organic and familial retardates with IQ's around 70. Normal groups matched on MA or CA were also tested. In the dichotic listening task, pairs of items are presented simultaneously, one item to the right ear, the other item to the left ear. After several pairs have been presented, *S* is asked to recall as many items as possible. The stimulus material consisted of digits, letters of the alphabet, or both.

The groups were consistently ordered on most performance measures: organic retardates were poorest; matched CA controls were best; familial retardates and matched MA controls were between and did not differ from each other. In some comparisons, the performance of the retardates differed qualitatively from that of normals. For example, retardates tended to stay with "ear order" recall (i.e., to recall all the items presented to one ear, then all those presented to the other) even for slow presentation rates at which more efficient temporal recall (i.e., recall of the items in sequential pairs from first to last) was

adopted by older children and adults. When mixed lists of digits and letters were presented, a child was asked to recall either in ear order or in type order (e.g., all the letters, followed by all the digits). Interestingly, retardates performed substantially better under type order than ear order, while normal children could recall equally well under both conditions. *Ss* were informed before each block of trials as to the recall procedure, so it is not possible to differentiate between storage or retrieval effects. However, the result is consistent with the hypothesis that retardates have a relatively restricted repertoire of encoding strategies and that, although they perform at a higher level when requested to handle information in an organized fashion, they do not tend to adopt such strategies spontaneously to the same extent as do normal children.

To summarize the results above, first, recall performance decreases at all delay intervals with decreasing MA and IQ. Since immediate recall (zero delay) decreases similarly, it seems reasonable to conclude that, for materials of the sort used (sequence of digits, letters or words), basic reception or input ability is directly related to level of intellectual functioning. As to whether rate of forgetting also depends on MA, the evidence is somewhat mixed, but the studies reviewed do not provide convincing support for the hypothesis that retardates forget more rapidly than normals.

Secondly, memory processes of children at various ages and IQ levels exhibit RI and PI effects qualitatively similar to those observed in college students. Few quantitative comparisons can be made, however, because experimenters seem compelled to make "slight" changes in procedure and materials, and few genuine developmental studies are available.

Finally, organizational variables appear to affect STM performance in retardates (and perhaps normal children) to an even greater extent than in normal adults. It is possible that the poorer recall ability of retardates reflects inadequate recording or organizational strategies, rather than an inherent limitation in STM capacity.

III

SHORT-TERM RECOGNITION MEMORY IN CHILDREN

In a serial recognition memory task *S* is presented a list of items (such as pictures of familiar objects) one at a time, and then shown a test item and asked to point out the corresponding item in the presentation list. For example, in a procedure used with young children, a series of animal cards are presented one at a time and turned over to form a face-down array. The child is shown a test card and asked to point to the matching card in the face-down array. In this task, verbal responses are not required of the children, and the stimulus materials can be assumed to be of approximately equal familiarity to children of various ages and IQ levels.

In five studies using the card-guessing technique with children (Atkinson, Hansen, & Bernbach, 1964; Bernbach, 1967; Calfee, Hetherington, & Waltzer, 1966; Ellis & Munger, 1966; Hansen, 1965), the procedures used were almost identical, permitting comparison of several relevant variables. The study by Bernbach (1967) evaluated the effect of overt rehearsal on recognition memory. The stimulus materials were cards, each in one of 4 colors. A trial consisted of the presentation of 4, 6, or 8 cards at a 2-sec. rate. Then the experimenter pointed to one of the cards, and the child pointed to the corresponding color on a multiple-choice test card. The children were 4- and 5-year-olds from a Cornell University nursery school, presumably from professional, upper-middle income homes. Children in one group said the color of each card as it was presented, while the other group observed the cards in silence. The labeling group was more often correct, especially in recalling the colors of the first cards in the list, than the silent group. Bernbach concluded that differences between children and adults in STM performance arose because adults automatically attach verbal labels to stimulus materials, but children have to be directed to do so. However, college students also did substantially better when required to label the stimuli than when they passively observed (Atkinson & Shiffrin, 1968).

In three studies. Atkinson et al. (1964), Ellis and Munger (1966), and Hansen (1965), the display consisted of 8 cards chosen randomly on each trial from a larger set of 11 or 12. The study by Ellis and Munger (1966) is especially useful because it provides information on task variables as well as comparative data on the performance of normal and retarded children. The cards are usually presented from the *S*'s right to left, so that spatial and presentation positions are perfectly confounded. Ellis and Munger found that with reversed direction (left to right) recall of the first item presented was reduced slightly but significantly. There were no other noticeable effects. Normal and retarded children performed equally well, but the retarded group was older (CA = 20, MA = 10) than the normal controls (CA = 6). Atkinson et al. (1964) had previously found that 5-year-old children made more correct first choices than 4-year-olds, and Hansen (1965) reported a corresponding finding with 5- and 10-year-olds.

Hansen's procedure involved substantial delay between presentation of the last card and the actual test. After the first list was presented face-down, a second face-up array was laid down beside it. The experimenter pointed to a test card in the second array, and the child was asked to point to the corresponding card in the first array. The proportion of correct responses was much lower in this study than in others. Hansen also manipulated presentation rate (1 or 3 sec. per card) and found a slight but significant effect of this variable. Rate interacted with serial position in the same fashion as in the O'Connor and Hermelin (1965) study, i.e., at fast rates the initial items in the list were better recalled, and at slow rates the more recent items were better recalled.

In summary, these studies show that with a recognition task and quite simple stimuli, performance improves with increasing mental age and IQ. Serial position effects are similar to those found with college students performing serial memory tasks. All the studies

except Bernbach's (1967) presented evidence that recognition memory was not all-or-none. For example, second guesses following an error tended to be correct more often than would be predicted for chance guessing (Atkinson et al., 1964; Hansen, 1965), and incorrect choices tended to be from the neighborhood of the correct card (Ellis & Munger, 1966).

IV

EFFECTS OF VARIATION IN DISPLAY SIZE ON STM OF NORMAL CHILDREN

The experiments described in this section deal with the effects of display size or memory load on STM performance of normal pre-school children. Effects of certain procedural variables, viz., range of variation in display size and prior knowledge of the display size, were also investigated. Some of the data (Group S below) have been previously reported (Calfee et al., 1966). The results are reported here for purposes of comparison.

GENERAL METHOD

The stimulus materials consisted of a set of 11 brightly colored animal rummy cards. Prior to the experimental trials, the child was shown the cards one at a time and told the appropriate name (e.g., zebra) until he could go through the entire deck and name the animals. The test procedure was then explained and demonstrated by a few training trials. On each trial, a subset of cards was chosen at random, and one position designated as the test position. The subset was shown to the *S* at a 2-sec. rate; *S* named the animal; and the card was placed face down so that a horizontal array was formed. Immediately after the last card, a test card was held up, and *S* was asked to turn over the matching card in the array. If the first choice was incorrect, it was left face up, and the child picked another card. Additional cards were turned up until a match was obtained. During the intertrial interval (15 to 45 sec.), the experimenter arranged cards for the next trial and chatted with the child.

SUBJECTS AND PROCEDURE

The investigations below were carried out over a 2-year period. In the initial study, small sets (3, 4, or 5 items) were used. In the second study display size varied widely within *S*s (4, 8, or 11 items). The results of this study were surprising and led to two further studies. In the first, sets of 6 and 8 items were used (relatively long, but not widely variable), and in the second, which again used sets of 4, 8, or 11 items, *S* was informed of the display size prior to each trial.

*S*s in the first study, Group S (short list), were 38 preschoolers (CA = 4.1, range 3.5–5.0) from the Unitarian Society Nursery School, Madison, who were tested during the 1964–65 school year. Each child was brought to the experimental room where he was shown a collection of small toys and told that he might choose one toy as a prize. All *S*s received the toy of their choice at the end of the session. Three children who asked to be run again were given a second session a week or more after the first session. There were no noticeable differences between sessions, and the data of the second session were combined with those of the first session in the analyses.

In each testing session, there were 8 sets each of display sizes 3, 4, and 5, a total of 24. Each serial position was tested at least once for each display size, the selection of cards and test positions being otherwise random.

Group L (long list) contained 16 children (CA = 4.3, range 4.1–4.9) from the Preschool Laboratory, University of Wisconsin, Madison, who were tested in the fall of 1966. Nine of the children participated in second test sessions a week or more after the first, so that a total of 25 test protocols were obtained. Materials, training, and test procedures were identical to those of the previous study. Each child was tested on 14 sets per session; 6- and 8-item sets were tested once at each serial position. Ordering of lists and test positions was completely random. Before each trial, the experimenter indicated on a display board the number of items to be shown.

For two other groups of children, displays of 4, 8, and 11 items were used. In Group NK (no knowledge) were 16 children (CA = 4.6,

range 4.0—4.9) from the Preschool Laboratory, who were tested during the fall of 1965. Each child participated in two testing sessions, with an interval of 6 to 8 weeks between sessions. In one of the sessions, a 2-sec. presentation interval was used, and in the other a 4-sec. interval. Length of presentation interval made no significant difference; the data were collapsed over sessions.

In Group K (knowledge) were 14 children from the Neighborhood House, Madison, (CA = 4.6, range 3.5—5.0), who were tested in the spring of 1966. Each child participated in a single session with a 2-sec. interval.

For both Groups K and NK, a session consisted of 23 trials, each display size (4, 8, and 11) being tested once at each serial position. Display size and test position were randomly selected on each trial. In Group NK, the cards were simply placed on a table in front of the child. Performance of this group was extremely poor. The children seemed confused by the wide variation in display size. Group K was run subsequently to determine the effect of informing *S* prior to each trial about the number of cards in the set.

At the beginning of each trial, display size was indicated by means of a presentation tray with 11 sections. Those sections not being used on a trial were covered with a masonite panel, so that on a 6-item trial, only 6 sections were uncovered, etc. The use of the tray was explained to the child during pretraining.

RESULTS AND DISCUSSION

In Table 1 are summary statistics for the first response on each trial. (Throughout this paper, position 1 is the last item presented, and successively larger position numbers refer to successively earlier cards.) The entries in the table are the sums over all test positions of the proportion of correct responses. For example, with a 3-item list, the proportion of correct responses on tests of the first, second, and third positions was .85, .68, and .37, respectively. The sum, 1.9, provides an estimate of the number of items in memory when the test was made. This measure increased linearly with display size. The effects of display size are statistically reliable ($p < .01$) except for Group S ($p < .10$). Although there was a gain in the total number of items available in memory, the proportion of items relative to display size (also shown in Table 1) decreased with display size. The only data points which deviated markedly from the pattern just described were the 6-item list of Group L and the lists learned by Group NK. There is no apparent explanation for the first discrepancy; it presumably represents sampling error. The performance of Group NK will be considered later.

Further details of recognition memory performance are provided by the serial position functions. The data for Group S, 4-item list, presented in Table 2, illustrate the derivation of various statistics. Serial position curves are usually based on the *a priori* probability

Table 1. Summary Statistics for First-Choice Performance as a Function of Display Size in Normal Children: Mean Correct Responses Summed Over Test Positions, and in Parentheses, Proportion of Correct Responses

	Display Size					
Group	3	4	5	6	8	11
S	1.9 (.63)	2.1 (.53)	2.2 (.44)	-	-	-
L	-	-	-	1.9 (.31)	2.5 (.31)	
K	-	2.2 (.55)	-	-	2.9 (.36)	3.5 (.32)
NK	-	1.5 (.38)	-	-	2.0 (.25)	2.2 (.20)

Table 2. Illustration of How Serial Position Statistics Are Derived from Number of Times Position i Was Chosen When Position j Was Tested, Group S, 4-Item List

		Initial Choice 1	2	3	4	Row Total	*A Priori* Probability Correct
Correct Position	1	71	7	2	3	83	.86
	2	14	40	16	11	81	.49
	3	4	32	35	11	82	.43
	4	4	16	33	29	82	.35
Total in Column		93	95	86	54	328	
Total Column Errors		22	55	51	25	153	
Marginal Error Distribution		.14	.36	.33	.16		
A Posteriori Probability Correct		.76	.42	.41	.54		

Table 3. *A Priori* Probability of a Correct Response, Normal *Ss*

Group and Display Size	Correct Position 1	2	3	4	5	6	7	8	9	10	11
S - 3	85	68	37								
- 4	86	49	43	35							
- 5	93	34	38	20	35						
L - 6	84	28	16	20	04	36					
- 8	80	32	12	20	24	04	28	48			
K - 4	100	64	21	29							
- 8	93	50	29	21	21	07	29	35			
- 11	93	57	43	36	29	29	07	07	07	07	36
NK - 4	71	32	18	26							
- 8	71	45	36	13	10	0	10	19			
- 11	84	26	10	10	23	23	13	06	0	0	19
Atkinson et al. (1964)											
4-year olds	91	75	54	53	46	23	15	21			
5-year olds	95	85	69	71	50	45	41	33			
Ellis & Munger (1966)											
Right-Left	80	57	20	13	13	8	15	45			
Left-Right	82	62	17	10	10	8	28	23			

Note.—Decimals omitted.

of a correct response, the proportion of times that position i is correctly chosen when tested. For example, of the 83 occasions when position 1 was tested, there were 71 correct choices, for an *a priori* proportion of .86. *A priori* serial position curves for the various conditions are presented in Table 3. Four other sets of related data are shown for comparison. A marked recency effect is present under all conditions, but the primacy effect occurs less regularly and is generally small.

A second statistic of importance is the marginal error distribution. From Table 2, it may be seen that this distribution gives the proportion of errors at each position. For example, of the 153 errors, 22 or .14 of the total errors occurred when position 1 was incorrectly selected. The marginal error distributions for the various conditions of this study are shown in Table 4. The error distributions are clearly not uniform. There were more errors at the middle than the end positions. (Children in Groups L and NK departed from this pattern; they tended to pick the first or last cards presented, and then turn over successive cards until a match was made.) Ellis

Table 4. Marginal Error Distributions, Normal *Ss*

Group and Display Size	Correct Position										
	1	2	3	4	5	6	7	8	9	10	11
S – 3	18	60	22								
– 4	15	31	36	18							
– 5	13	21	40	16	10						
L – 6	13	16	20	14	05	32					
– 8	14	11	14	15	11	02	04	29			
K – 4	03	35	50	12							
– 8	03	25	19	26	10	08	04	04			
– 11	02	14	08	18	14	10	13	08	02	01	07
NK – 4	37	33	10	09							
– 8	29	15	18	14	10	02	03	10			
– 11	17	12	06	11	15	11	09	05	03	01	12

Note.—Decimals omitted.

Table 5. *A Posteriori* Probability of a Correct Response, Normal *Ss*

Group and Display Size	Correct Position										
	1	2	3	4	5	6	7	8	9	10	11
S – 3	81	50	62								
– 4	77	42	41	54							
– 5	73	38	25	31	55						
L – 6	62	29	17	25	17	22					
– 8	52	35	13	19	29	25	57	23			
K – 4	93	50	19	57							
– 8	87	28	22	14	30	14	57	62			
– 11	87	35	40	21	21	27	07	11	25	50	.39
NK – 4	54	28	43	35							
– 8	29	33	25	14	14	0	33	25			
– 11	36	10	15	09	14	18	14	12	0	0	15
Atkinson et al. (1964)											
4-year olds	81	65	47	38	34	22	33	63			
5-year olds	84	79	68	54	44	49	43	74			
Ellis & Munger (1966)											
Right-Left	78	28	20	22	25	14	21	29			
Left-Right	75	28	20	18	20	11	25	25			

and Munger (1966) and Atkinson et al. (1964) also reported a bias for the middle positions.

Parenthetically, it should be noted that this bias for the middle cards when uncertain is a reasonable guessing strategy. Since the child can often remember the location of the first and last cards, if a test item is difficult to locate in memory it is likely to be from the middle of the list.

As several investigators (e.g., Murdock, 1966) have recently pointed out, *a priori* functions are sensitive to both memory strength and response strategies. For example, *S* can increase the *a priori* probability of a correct response at position *i* by selecting it more often when uncertain. Another way of analyzing the data which is less sensitive to differential response strategies is to estimate the *a posteriori* probability of a correct response. This is the likelihood that *S* is correct when he selects position *i*. For example, in Table 2, position 1 was chosen 93 times of which 73 were correct choices for an *a posteriori* probability of .81.

The *a posteriori* serial functions shown in Table 5 are generally quite orderly. Except for Group L, 6-item list, all the data have the bowed shape characteristic of adults. Response strategies, particularly the tendency to select the middle position, appear to have

been responsible for the absence of primacy effects in certain of the *a priori* functions in Table 3. In the Ellis and Munger (1966) study, it was concluded from the *a priori* function that the first card presented was better recalled when the cards were presented from right to left. From the *a posteriori* function, it can be seen that this result is due to response bias rather than to differential memory strength.

Next, we turn to the question of partial versus all-or-none retention. Two findings indicate that, when the first response was incorrect, the child nonetheless had some information about the correct position. First, when S's first choice was wrong, the position selected tended to be closer to the correct position than chance guessing would predict. Second, second guesses following an error tended to be correct more often than would be expected by chance.

Evidence for the first finding comes from the average absolute deviation (AAD) of initial choices. Referring to Table 2, it can be seen that in testing position 3, position 2 was selected 32 times, and position 4 was selected 11 times. Both positions are one removed from the correct location. There were 4 errors at position 1 which is two cards from position 3. The AAD for position 3 was therefore equal to $[1 \times (32 + 11) + (2 \times 4)]/47 = 1.1$. By normalizing on errors, the measure was independent of error probability. If it were normalized on total responses, it would be smaller at shorter list lengths because there are fewer errors, and thus it would have provided a less sensitive indicant of error dispersion.

In Table 6 are observed and predicted AAD's for various groups and list lengths, averaged over serial positions. The predicted AAD's were based on the marginal error distributions. Again referring to Table 2, the probabilities that positions 1, 2, 3 were erroneously selected were .14, .36, and .33, respectively. In test position 4, there were 53 errors. If the child were simply guessing on errors, i.e., if he had no idea where the correct card was located, then the proportion of errors at position 1 would be $.15/(.15 + .31 + .36) = .18$. Thus, 9 errors are predicted at a distance of two cards from the correct location. The actual number of errors was 4. This difference between predicted and observed choices indicate generalization to the correct card at this position. For all but one entry in Table 6, errors cluster more tightly around the correct card than one would predict from all-or-none retention. Similar results were observed by Ellis and Munger (1966) and Atkinson et al. (1964). The extent of the effect is small but consistent.

With regard to the second-guessing data, an all-or-none retention model implies that if the first response is in error, S should be completely uncertain about the correct position, and so the second response should be selected at random from the remaining alternatives. The second and succeeding choices for list lengths of 3, 4, and 5 were analyzed in detail and the all-or-none retention hypothesis came close to account for these data (Calfee et al., 1966). However, there was a slight deviation in the direction of better than chance performance, and second guesses by other groups were correct more often than expected by an all-or-none hypothesis in all cases. The probability of a correct second choice for 6- and 8-item lists in Group L was .25 and .20, compared with chance predictions of .20 and .14, respectively. For Group NK on lists of 4, 8, and 11, the observed probabilities were .41, .15, and .10, and for Group K, .77, .33, and .18, compared with predictions of .33, .14, and .10, respectively.[2]

Although we were surprised at the effect of prior knowledge of list length on recognition memory in preschoolers, Pollack, Johnson, and Knaff (1959) reported a similar finding in college Ss. In their study of backward digit span, Ss could recall 1 to 2 digits more when they were informed of the length of the sequence prior to presentation than when they were not. The difference between Groups NK and K in mean probability of a correct response in our study was of the same order of magnitude (Table 1) and was statistically reliable, $F(1, 28) = 6.04$, $p < .05$. Children in Group NK tended to make stereotyped responses, such as starting at one end of the array and turning cards over in order, while children in Group K tended to select cards in the vicinity of the correct card. This difference in strategy is

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[2]For reasons mentioned previously, second-guess rates somewhat higher than chance might be expected if S differentially selected the middle positions. The exact guessing rates on second choices are tedious to compute for long lists. Exact predictions were obtained for a few representative samples, and it was found that the observed second-choice probabilities were greater than the predicted values in all cases. For example, in Group K, 4-item list, the prediction taking into account marginal error was .50, and the observed probability was .77.

Table 6. Average Absolute Deviation Between Correct Test Position and First Response, Normalized on Errors, Normal *Ss*. Predicted Values in Parentheses are Based on Assumption of Random Guessing from the Marginal Error Distribution

Group	Display Size					
	3	4	5	6	8	11
S	1.1 (1.2)	1.4 (1.5)	1.6 (1.8)	-	-	-
L	-	-	-	2.5 (2.5)	3.1 (3.2)	-
K	-	.8 (1.5)	-	-	2.0 (2.6)	2.7 (3.6)
NK	-	1.5 (1.7)	-	-	3.2 (3.1)	3.8 (4.1)

apparent in Table 6, where the difference between observed and expected AAD's was much smaller for Group NK than for Group K.[3]

In summary, the investigations of display size justify several preliminary conclusions about STM capacity in young children. (a) As memory load increases, mean probability of a correct response recall decreases but at a lower rate than the increase in load, producing a net gain in amount of information retained. Within the limits examined, total amount remembered increases linearly with display size. (b) Noticeable response biases occur. When unsure (i.e., given an error), children tend to select a card from the middle of the list. (c) When response biases were taken into account, primacy and recency effects similar to those in college-age *Ss* are found. (d) Second-guess and generalization analyses are contraindicative of a simple all-or-none retention model. When the initial response was wrong, the erroneous choice was usually in the vicinity of the correct position, and the second choice was correct more often than predicted by chance. In most respects, the performance patterns of young children seem to parallel those of college students on similar tasks, the main difference being the higher rate of forgetting and the existence of greater response biases in children.

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[3]It is true that certain variables are uncontrolled in this comparison—*S* population, time of year, and experimenter. Judging from a comparison of *Ss* in the studies of Atkinson et al. (1964) and Hansen (1965) with those of Ellis and Munger (1966) and Group L in the present study, subject population is probably a variable of some significance. *Ss* in the first two studies generally performed at a substantially higher level than those in the latter two. The latter groups came from preschool nurseries catering to upper-middle class parents, while the former groups were from day-care centers and low-income backgrounds. In our experience, children from day-care centers, where relatively little individual attention may be available, appeared more strongly motivated and interested in the experiments.

V

EFFECTS OF LIST LENGTH VARIATION IN MENTAL RETARDATES

The review of the STM recall literature indicated that compared to normal children of the same MA, retarded children have generally performed rather poorly. Most studies involved long test sessions, although retardates seem more affected than normals by PI, or fatigue, or both. Digits frequently served as stimulus material; hence, to the extent that normals (more than retardates) spontaneously organize digit strings, the outcome of the experiments may be interpreted as reflecting differences in capacity, forgetting rate, encoding ability or any combination of these. In only one study (Neufeldt, 1966) was attention given to the diagnostic classifications of the retardates, and it proved to be a significant variable.

The studies reported below tested serial recognition memory in retardates of various IQ levels and diagnostic categories, using essentially the same procedures and materials as the preceding series of experiments with normal children.

METHOD

The experimental procedure used to test retardates was similar to that used with normals in most respects. The main differences in procedure were that (a) retardates were given more extensive pretraining than were normals, (b) retardates were tested for more sessions than were normals, and (c) retardates were given immediate reward in the form of M & M candies at the end of each trial.[4]

Retardates were given two preliminary sessions with 3-item sets. First, the children were shown each card, told the common zoological name, and asked to repeat it. Throughout subsequent testing, *S*s were reminded if necessary to name the animal on each card. For some of the more severely retarded, a muttered acknowledgement was all that was possible. After stimulus familiarization, the child received pretraining trials with 3-item sets until *E* was satisfied that the child understood the task. All of the *S*s selected for testing had satisfactorily mastered the task by the end of the second session.

During the next 8 sessions, each *S* was tested on sets of 3 to 5 items. There were then 2 to 4 sessions in which sets of 6 and 8 cards were used.[5] With the larger sets, *S* was informed of list length prior to each trial. There were 16 trials per session on the 3 to 5 item sets, and 14 trials per session on 6 and 8 item sets. The presentation rate was 2 sec. per card. Each session lasted from 15 to 20 minutes.

SUBJECTS

Three groups of mental retardates were tested. Group MH consisted of 12 children (CA = 7.5, range 5–10), severely to moderately retarded (IQ = 44, range 30–70; MA = 3.9, range 2–5); 7 were mongoloids and 5 were

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[4]The retardated *S*s received more extended pretraining and familiarization and, except for Group EF, were tested more extensively than were the normals. So far as the number of training sessions is concerned, in the testing of neither normals nor retardates have we seen any evidence of improvement over sessions past the pretraining period; the intersession interval has always been a week or more. With regard to pretraining, it is always possible to raise questions about the importance of interpersonal relations in testing and the comparability of test conditions, among other equally sticky matters which have been discussed recently by Zigler (1967).

[5]All *S*s were to have been tested at four sessions with the longer display sizes, but the testing program was unexpectedly terminated due to an outbreak of infectious hepatitis.

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hydrocephalics. Half were boys, and half girls. Group OR included 10 older subjects (CA = 21, range 16–29), also severely to moderately retarded (IQ = 37, range 25–65; MA = 3.5, range 2–6), who had been classified under a variety of organically related categories, such as maternal toxemia. All were tested during the 1964–65 school year. In Group EF were nine educable familial retardates (CA = 10.6, range 10–11; IQ = 65, range 54–81), who were students in a special education class at Lowell School, Madison. Five were male, four female. Testing was carried out during the spring of 1966. This group was tested only once at each display size, one day with lists of 3 to 5 items, and a second day with lists of 6 or 8 items. They received a single day of preliminary training.

RESULTS AND DISCUSSION

Summary statistics for the various groups of retardates are presented in Table 7. In Tables 8 and 10 respectively are the *a priori* and *a posteriori* probabilities of correct response, and in Table 9 are the marginal error distributions. The most noticeable feature of the data is its similarity to the previous data from the normal preschoolers. Analysis of variance of the mean number of correct responses, comparing Group S and the 3- to 5-item data of the three retarded groups, indicated that display size was a significant variable, $F(2, 136) = 4.86$, $p < .01$ as was the variability among groups, $F(3, 68) = 3.09$, $p < .05$. A subsequent Duncan range test showed that Group S performed less well than Group MH, the difference just reaching a conventional level of significance ($p < .05$).

In comparison of Group L and the three retarded groups, display sizes of 6 and 8 items, Groups was significant, $F(3, 27) = 2.9$, $p < .05$; the difference between Groups L and EF reached a conventional level of significance ($p < .05$) by a range test. In both analyses, the normal preschoolers made ***more*** errors than the retardates. However, the actual magnitude of the differences among the groups in mean number of correct responses was relatively small.

The pattern of serial position effects was also the same for normals and retardates. Retardates chose the middle positions on errors, and produced *a posteriori* curves characterized by both primary and recency effects. Finally, AAD data from retardates (Table 11) indicates a degree of error generalization around the correct position quite similar to that found in normal children.

While there are problems in comparing *S*s from normal and retarded populations, in our opinion the pretraining procedures used in these experiments produced comparable test conditions for the various groups, and the stimulus materials minimized effects of differential organizational ability. Those procedural details directly related to the experimental variables, such as presentation rate, number of trials per session, etc., were the same for all groups. Hence, it seems justifiable to conclude that when organizational factors are minimized, i.e., for relatively short lists of distinctive items, normal and retarded individuals matched on MA do not differ in STM capacity.

As mentioned previously, retardates generally perform more poorly than normals on recall tasks using more abstract stimuli such as digit strings. It seems quite possible that

Table 7. Summary Statistics for First-Choice Performance as a Function of Display Size in Retardates: Mean Correct Responses Summed Over Test Positions and, in Parentheses, Proportion of Correct Responses

	Display Size				
Group	3	4	5	6	8
MH	2.3 (.77)	2.4 (.60)	2.7 (.54)	2.6 (.43)	2.9 (.36)
OR	2.2 (.73)	2.3 (.58)	2.5 (.50)	2.7 (.45)	2.9 (.36)
EF	1.9 (.63)	2.1 (.53)	2.3 (.46)	2.9 (.48)	3.1 (.39)

these latter tasks involve factors other than STM capacity, viz., organizational or encoding ability, and that these other factors are more directly the source of poor performance by retardates. The study reported below was directed toward this question.

Table 8. *A Priori* Probability of a Correct Response, Retarded *Ss*

Group and Display Size	Correct Position							
	1	2	3	4	5	6	7	8
MH-3	93	75	61					
-4	98	68	40	32				
-5	99	59	35	30	47			
-6	95	53	25	27	17	47		
-8	100	73	16	15	22	13	11	39
OR-3	87	75	60					
-4	84	43	51	55				
-5	90	40	33	40	47			
-6	93	36	26	16	42	54		
-8	77	36	12	14	30	44	15	65
EF-3	89	67	33					
-4	89	44	44	33				
-5	89	56	22	11	56			
-6	100	67	11	22	44	44		
-8	89	67	44	0	11	22	22	56

Table 9. Marginal Error Distributions, Retarded *Ss*

Group and Display Size	Correct Position							
	1	2	3	4	5	6	7	8
MH-3	15	60	26					
-4	08	36	29	26				
-5	03	26	32	22	16			
-6	07	31	24	14	04	20		
-8	07	24	10	13	12	06	04	24
OR-3	15	48	38					
-4	16	30	35	20				
-5	09	19	33	26	13			
-6	09	11	19	27	08	27		
-8	03	14	08	07	23	11	09	26
EF-3	0	70	30					
-4	0	19	50	31				
-5	0	21	25	25	29			
-6	04	18	11	25	21	21		
-8	0	07	20	05	16	07	20	25

Table 10. *A Posteriori* Probability of a Correct Response, Retarded *S*s

Group and Display Size	Correct Position							
	1	2	3	4	5	6	7	8
MH-3	90	64	78					
-4	89	54	47	50				
-5	93	50	32	37	55			
-6	79	34	25	36	53	41		
-8	73	38	25	17	26	31	31	25
OR-3	88	65	71					
-4	76	46	48	62				
-5	81	48	28	39	57			
-6	77	50	30	13	65	40		
-8	77	28	22	33	22	45	27	32
EF-3	100	46	50					
-4	100	57	38	38				
-5	100	50	25	14	41			
-6	90	54	25	22	40	40		
-8	100	67	31	50	13	40	18	31

Table 11. Average Absolute Deviation Between Correct Test Position and First Response, Normalized on Errors, Retarded *S*s. Predicted Values in Parentheses are Based on Assumption of Random Guessing from the Marginal Error Distribution

Group	Display Size				
	3	4	5	6	8
MH	1.1	1.3	1.5	2.0	2.7
	(1.2)	(1.4)	(1.6)	(2.1)	(3.0)
O	1.2	1.3	1.5	1.8	2.6
	(1.2)	(1.4)	(1.6)	(2.1)	(2.8)
EF	1.0	1.2	1.4	1.7	2.0
	(1.0)	(1.3)	(1.5)	(1.9)	(2.5)

VI

ORGANIZATIONAL FACTORS IN STM OF NORMAL AND RETARDED CHILDREN

The study reported below was an extension of a procedure used by Calfee and Peterson (in press) to investigate organizational effects in STM performance of college students. For the younger *S*s, the card-guessing format employed stimuli consisting of two sets of conceptually related items. On each trial, the set was presented in a fashion that maximized the perception and utilization of the concepts, or such that the concepts were neither obvious during presentation of the list nor of particular utility during recall.

METHOD

The stimulus cards were 28 pictures of familiar objects. There were 4 items in each of 7 categories—animals, toys, food, parts of the body, geometrical shapes, articles of clothing, and colors. For example, the 4 items in the animal category were a dog, a cat, a horse, and a bird. The set of materials was tested and revised until each of 10 4-year-olds (from the University Preschool Laboratory) could name every card and could sort the cards by category. In the sorting task, a child was presented with cards from 2 categories, and asked to arrange the cards into 2 piles. This operation was repeated until all pairs of categories had been sorted.

The pretraining and testing procedures were identical to those previously described. On each test trial, a series of 6 cards was shown to the child. As each card was presented, *S* pronounced the name of the item. After the last card, a test card was shown, and *S* pointed out the matching card in the presentation set. If the initial guess was wrong, additional cards were turned over until the matching card was found.

Three types of sets were prepared. Control (X) sets consisted of one card from each of 6 categories. High (H) and low (L) organization sets consisted of 3 cards from each of 2 categories. In H sets, all 3 items in one category were presented first, followed by the 3 items in the second category. Thus, the sequence was of the form AAABBB. In L sets, the cards were arranged randomly, excluding sequences of the form AAABBB or ABABAB. An example of an L set might be DOG, FOOT, ARM, BIRD, CAT, EAR.

Each child participated in 3 sessions or more of about 15 min. each. During the first session, the child was introduced to the task using animal rummy cards as stimuli. He was then shown the new "category" materials until each card could be named. Tests were run in 6-trial blocks. Within each block one type of set, X, H, or L, was presented, each serial position being tested once. The conceptual arrangement of the lists was never pointed out to *S*s.

SUBJECTS AND PROCEDURE

Three groups of *S*s were tested, 20 nursery school children, 15 sixth graders, and 9 educable mental retardates, groups NS, 6G, and EF, respectively. Testing was conducted during the spring of 1966.

Group NS from the University Preschool Laboratory was comprised of 20 normal preschoolers (CA = 4.6, range 4.3—5.0). Group 6G were *S*s from an upper-middle-class school (CA = 12.7, range 11.9—13.2). For these two groups, three 6-trial blocks were presented during the first testing session. For half the *S*s, the blocks were arranged in order X-H-L; for the others, the order was X-L-H. Thus, X sets were presented to all *S*s on the initial block of trials, followed by H and L sets in a counterbalanced order. In the second test session, order X-L-H was used if a child had originally received order X-H-L, and vice-versa.

The retarded children were the same *S*s previously described as Group EF. Following 3 days of familiarization and training with animal rummy cards, there were 4 days of

Table 12. Proportion of Correct Responses and Intracategory Errors as a Function of List Organization in Normal (NS and 6G) and Retarded (EF) Children

	List Organization				
	Control	Low		High	
Group	Correct Responses	Correct Responses	Intracategory Errors	Correct Responses	Intracategory Errors
NS	.47	.46	.50	.53	.63 (.43)[a]
6G	.58	.67	.76	.75	.65 (.44)
EF	.58	.57	.43	.55	.69 (.47)

[a]Proportion of intracategory errors predicted from control lists.

testing on the organized sets. These children were very restless during pretraining and so were given only 2 blocks of 6 trials each per day. For 4 of the *Ss*, the block order over the 4 days was X-H, X-L, H-L, L-H, and for the remaining *Ss*, the order was X-L, X-H, L-H, H-L.

RESULTS

The major findings appear in Table 12. Organized sets were better remembered than were control sets by normal children as early as nursery school. The difference between mean probability of a correct response on H and L sets was statistically significant for Groups 6G ($F(1,16) = 4.5$, $p < .05$) and NS ($F(1,12) = 10.1$, $p < .05$). The difference in recall of the X and L by Groups 6G and NS was not statistically reliable. The performance of Group EF did not differ as list structure was changed.

The differences associated with the organizational variable are not large in absolute magnitude. For example, mean number of correct responses in Group 6G rose from 4.0 to 4.5 items when the structure was changed from low to high organization. However, while 9 *Ss* made fewer errors on H sets than on L sets, 3 made more errors and 5 did equally well on both. This degree of consistency was reflected in the statistical test.

More detailed analysis of the data showed that the structure of the set limited *S*'s choices, even when the first card selected was incorrect. In highly organized lists, errors tended to fall within the appropriate category more frequently than would be predicted from the degree of generalization in control lists.[6] This effect is apparent in the observed and predicted proportions of intracategory errors on L and H sets (Table 12). Interestingly enough, although structure did not enable retardates to remember the set any better, they were not insensitive to the structure. All groups, normal and retarded, made more intracategory errors than were predicted for H sets, but not with L sets.

A priori and *a posteriori* serial position curves were computed for each condition (Table 13). *A posteriori* functions are again

[6]The proportion of intracategory errors is always greater for H than for L or X lists, but this effect is in part artifactual. Consider the form of a response matrix for a typical series as in Table 2. Only errors entered into the analysis so that the frequencies along the main diagonal are disregarded. If this were an H series, correct category responses would be those off-diagonal entries in the upper left and lower right quadrants. These cells are closer to the diagonal than are the remaining cells, and so would be expected to have relatively larger frequencies because, as previously shown, incorrect responses tend to fall in the vicinity of the correct position. Since in H series all items in a category are close together, if a child has a rough idea of the correct position, he should, as a result of generalization (or partial recall), tend to choose from the correct category relatively more frequently than on an L series, in which the category items are spread out. The question is whether or not, over and above generalization, errors tend to fall within category boundaries. The X series provide a suitable measure of generalization for comparison with H series performance, and so the predicted correct category probabilities in Table 12 indicate the proportion of off-diagonal entries in the upper left and lower right quadrants of the X series.

Table 13. ***A Priori*** and ***A Posteriori*** Probability of a Correct Response in List Organization Experiments

Group and List Organization	Correct Position: *A Priori* 1	2	3	4	5	6	*A Posteriori* 1	2	3	4	5	6
NS - X	84	72	24	16	28	60	91	40	29	16	58	63
- L	94	66	31	19	22	44	81	42	24	32	41	52
- H	91	72	25	38	34	59	91	53	31	43	50	45
6G - X	100	53	[illegible]3	36	50	75	100	83	33	33	42	50
- L	100	82	76	35	53	53	100	88	48	43	60	69
- H	100	77	94	71	47	59	100	87	71	55	67	71
EF - X	100	86	45	25	36	53	100	65	39	36	43	54
- L	98	78	38	32	41	52	96	62	33	35	50	65
- H	95	67	51	27	43	44	97	58	47	34	42	55

more appropriate because of the strong bias for the middle positions. These functions closely resemble other data reported in this paper. In the Calfee and Peterson (in press) experiment, primacy and recency effects were found for each of the subcategories in highly organized lists, so that there was a hump in the middle of the serial position curve. There was little evidence of such a hump in the present study, except possibly in Group 6G. An 8-item list was used by Calfee and Peterson, and may have provided a more sensitive picture of serial position effects.

VII
GENERAL DISCUSSION

The data presented above suggest that, apart from differences in rate of forgetting, serial recognition memory processes in young children are similar to those in adults. Moreover, retarded children perform such tasks in a manner which is not significantly different from that of normals of the same MA. Primacy and recency effects as well as response strategies were similar in most essentials among all groups tested.

Within the conditions of the present experiments—short lists, distinct items, and a recognition testing procedure—the actual performance levels achieved by most *S*s are virtually identical. This constancy must finally break down, since college students can perfectly remember lists of 5 items or less. Moreover, when larger lists are used, younger children do more poorly than older children (Atkinson et al., 1964; Hansen, 1965). However, for the age range tested in the studies reported in this paper, the effects of variation in age and IQ are negligible compared with the effect of display size.

Further evidence for the similarity of STM processes arises from the generalization analyses. Errors tended to be in the neighborhood of the correct response. If the first response was wrong, chances were good that the second choice would be correct. The better-than-chance performance observed on these measures might have been due either to incomplete retention of information about the test position (e.g., "tiger is either the third or fourth card"), or to a process of elimination (e.g., "I remember that the first card was an elephant, and the second was a zebra, so the tiger must be either the third or fourth"). There is no way of determining the relative importance of these two strategies. One possibility is that an elimination strategy produced the error distribution, and that partial memory led to generalization around the correct position on first choice and the higher than expected second-guess rates.

Retardates did differ from normals in their ability to make use of the organization of a list. The significantly higher recall of organized as opposed to unorganized sets by normal preschoolers indicates that the tendency to make use of organization is acquired quite early. The performance of the older children suggests that organization plays an increasingly important role in storage of information. Retarded children in this study were not completely insensitive to set organization, but they were unable to use the organization to improve performance. This finding, taken together with Spitz's (1966) work and the finding of encoding deficits in retardates (Headrick & Ellis, 1964; O'Connor & Hermelin, 1965), suggests that the poorer performance generally characteristic of retardates results not from reduced capacity in short-term or long-term memory, nor from a faster rate of loss of information in either system, but rather from an impaired ability to transfer information between these memory systems.

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